

The impact of Information and Communication Technologies on financial inclusion in South Africa: The role of institutional quality.

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Abstract

While financial inclusion is broadly recognised as a primary engine of development and poverty reduction. The factors that determine it are under-researched. This creates a gap, particularly concerning the effect of Information and Communication Technologies (ICT) on financial inclusion. Therefore, the main objective of this paper is to examine this linkage using the Autoregressive Distributed Lag (ARDL) method in South Africa between 2000 and 2022. Furthermore, the paper examines the moderating effect of institutional quality on the financial inclusion-ICT nexus. The Principal Component Analysis (PCA) was used to generate the financial inclusion and ICT indices. The Fully Modified Ordinary Least Squares (FMOLS) was used as the robustness check estimator. The empirical findings indicate that ICT development enhances financial inclusion. At the same time, institutional quality has a direct negative impact on financial inclusion. Also, the findings indicate that institutional quality erases the positive effect of ITC on financial inclusion. This calls for the South African government to revamp its digital technology infrastructure and strengthen institutional quality to improve financial inclusion in the country. The study concludes with policy recommendations on ICT-financial inclusion initiatives in South Africa.

1. Introduction

Financial inclusion is widely recognised as a fundamental catalyst for economic growth, poverty reduction and inequality mitigation across diverse economies (Khan et al., 2022; Chidimma Maria-Gorretti Umeaduma, 2023; Mbodj & Laye, 2025). This concept is not only about holding a bank account, but it entails a household or individual's access to and use of formal financial services, including payments, savings, credit, and insurance, provided responsibly at an affordable cost (World Bank, 2024; FinMark, 2025). In the specific context of South Africa, this means ensuring that all individuals and Small, Medium, and Micro Enterprises (SMMEs) have access to and can effectively use quality products and services offered by a regulated financial sector (Department of National Treasury South Africa, 2023). However, even if financial inclusion is considered a key driver of critical socioeconomic factors, the current socioeconomic trajectories, characterised by extreme inequality, high unemployment, persistent poverty, and lower growth, appear to contradict this established relationship across developing economies, and South Africa is no exception.

South Africa's financial inclusion journey has demonstrated considerable improvement since 2000. For instance, formal financial services across the population grew significantly, from 55% in 2003 to 98% in 2023. Again, the percentage of account holders for the adult population increased from 52% in 2003 to 84% in 2023 (Mutsonziwa & Berkowitz, 2025). Regarding availability, key infrastructure metrics have also improved. The number of bank branches per 100,000 adults was recorded at 30.66, and the number of Automated Teller Machines(ATMs) per 100,000 adults at 50.6 in 2021 and 2023, respectively. As for usage, the credit-to-private-sector ratio, as documented by the Global Economy Database (GED) (2022), reached 112% in 2020. Nonetheless, despite these substantial gains in financial access and availability, the South African economy continues to present a sharp divergence. It remains the most unequal economy globally, with a Gini coefficient of 0.67 and an estimated 63.4% poverty (2024), a high unemployment rate of 32.9% (2023), and real GDP growth at a mere 0.6% (2023), continuing a long-term declining trajectory since 2008 (World Bank, 2022; Naidu, 2023; Mabugu, 2024).

Furthermore, despite having one of Africa's most developed banking sectors, South Africa continues to face persistent financial exclusion as progress has been disproportionately focused on the access dimension (Financial Sector Conduct Authority (FSCA), 2020; Nanziri & Gbahabo, 2025). Indeed, high rates of account ownership do not automatically translate to tangible improvements in financial well-being and overall economic outcomes, primarily due to strict documentation requirements, limited financial literacy among vulnerable populations, high transaction costs, and the physical distance to service providers. For instance, some rural communities are located up to 80km from the nearest formal service provider (Simatele & Maciko, 2022). Additionally, approximately 51% of South Africans are considered financially literate in 2020, while nearly half (49%) of the adult population lacks the basic skills necessary to manage their finances effectively (Nanziri & Leibbrandt, 2018; FSCA, 2020; Millen & Stacey, 2022). Furthermore, issues of trust and costs are noticeable. For example, banking fraud represents 45% of all reported fraud incidents in 2021, and about 33% of account holders utilise their accounts merely as mailboxes, primarily citing poverty and associated costs (Genesis Analytics & Financial Sector Conduct Authority, 2022; Department of National Treasury South Africa, 2023; Nanziri & Gbahabo, 2025). Such a disconnect between widespread financial access and persistent socio-economic distress is not only a data anomaly but also represents a fundamental failure of access to yield meaningful usage and tangible well-being. This highlights a crucial need to examine the quality of inclusion and the underlying factors that hinder its theoretical potential in South Africa.

Given the limitations of traditional financial models, analysts, the media, and academic literature (Olaniyi, 2016), have consistently emphasised the transformative potential of digital technology in advancing financial inclusion. This observation leads to the critical question "Can technology development effectively spur the inclusion of the financially excluded poor in South Africa?" In developing economies, including South Africa, technological advancement has been primarily driven by the rapid diffusion of ICT modalities (Astuti & Ayinde, 2025). ICT encompasses the growth and accessibility of various technologies, such as mobile phones, internet connectivity, digital payment systems, and fintech innovations. (Ahmad et al, 2023; Bawuah, 2024). These are projected to enhance digital access, thereby reducing reliance on physical bank branches (Li, Chen & Lu, 2022). Consistently, Tillemann (2022) and Ramayanti et al. (2024) posit that ICT facilitated digital payments, which minimise

cash dependency and reduce the overall costs of service provision, through automation. Therefore, a thorough examination of how ICT technologies influence financial inclusion is crucial for formulating clear and effective financial inclusion policies in South Africa.

The stability of the financial environment and consumer confidence in South Africa are continually undermined by escalating concerns, including advanced fraud (phishing/vishing), cybersecurity threats, illegal financial flows, physical attacks on infrastructure (ATM bombings, cash-in-transit heists) and consumer protection lapses (Ncube, 2024). These pervasive issues are likely linked to institutional deficiencies and inconsistent regulatory enforcement. Therefore, as the current study examines the relationship between ICT and financial inclusion in South Africa, it is crucial to incorporate the foundational factors that dictate the country's operational efficacy. Institutional quality is thus identified as a critical determinant, as it incorporates the rules of the game in a society or an economy that shape incentives and guide behaviour (North, 1990; Acemoglu et al., 2003). Institutional quality encompasses areas such as the rule of law, effective governance, control of corruption, and political stability, which underpin economic progress. Academic studies, including those by Acemoglu, Johnson, and Robinson (2003) and Chinoda and Kwenda (2019), substantiate its importance as a key driver of enhanced financial inclusion. Consistently, Ferrini (2012) and Kovač and Spruk (2016), posit that the quality of institutions significantly influences the country's economic development trajectory by reducing transaction costs, protecting property rights, and enhancing trust between institutions and citizens. Therefore, this study examines how the efficacy of the ICT-financial inclusion relationship is profoundly influenced by South Africa's institutional quality.

While existing literature links ICT to financial inclusion, most of the related studies are survey-based (Lapukeni, 2015; Ogbuabor et al., 2020), rely heavily on regional or cross-country analysis studies (Bayar, Gavrilitea & Păun, 2021; Doku et al., 2023) and predominantly examine the socio-economic impacts of financial inclusion, such as poverty, economic growth and inequality (Chinoda & Kapingura, 2024). Similarly, existing literature has also emphasised the importance of the institutional quality framework. However, empirical attention to the determinants of financial inclusion, the relationship between technological development factors and financial inclusion, and the moderating effect of institutional quality on the financial inclusion-ICT nexus remains underexplored, particularly in developing economies such as South Africa.

Critically, research specifically employing econometric methods to examine the effect of ICT on financial inclusion and the moderating impact of institutional quality in South Africa is notably scarce despite the country's unique institutional development path and high ICT adoption alongside persistent financial exclusion. This scarcity of empirical studies has been identified as a key factor in inadequate policy guidance for leveraging ICT to enhance financial inclusion (Roycroft & Anantho, 2003). In doing so, the current study fills a specific void by evaluating the direct effects of ICT technologies on financial inclusion in the South African economy between 2000 and 2022. Thus, the study's contribution to the ongoing discourse on financial inclusion stems from its inclusion of ICT and the moderating effect of institutional quality into the financial inclusion model. The study makes a theoretical contribution by shedding light on the complex relationship between technology and governance, particularly by offering targeted digital technology policy recommendations to enhance financial inclusion in the South African context.

The following section provides an overview of the outlook on ICT and financial inclusion in South Africa. The third section motivates this paper through a description of the existing literature. The fourth section presents the data and methodology used to assess the impact of ICT on financial inclusion in South Africa. The empirical results are presented in Section 5. The last section concludes the paper.

The impact of ICT and the moderating effect of institutional quality on financial inclusion are explained by the Technology Acceptance Model (TAM), the Diffusion of Innovations, and the New Institutional Economics.

1.1. Theoretical Literature

The Technology Acceptance Model (TAM) suggests how users accept and use technology as the criteria for accepting or rejecting a particular technology (Davis, 1985; Fred, 1987; Thathsarani & Jianguo, 2022). It hypothesises that the perceived ease of use and usefulness influence users' attitudes toward technology, eventually affecting their intention to use and actual usage (Tahar et al., 2020). This theory is

relevant to the ICT and financial inclusion relationship because ICT innovations, such as mobile banking, need to be perceived as easy to use and beneficial to users to adopt them, leading to greater financial inclusion (Wibella, Fahmi & Saptono, 2018).

The Diffusion of Innovation theory advocates for guiding technological innovation, where innovation itself is modified and presented in ways that meet the needs of all adopters across various levels (Rogers, 1995; Wejnert, 2002). Thus, for the financial inclusion-ICT relationship, the theory implies that through diffusion of innovation, ICT facilitates financial inclusion by spreading financial technology across populations, with early adopters influencing others (Ryan & Gross, 1943; Dearing, 2009). As a result, the speed and manner of this diffusion can significantly affect financial inclusion rates.

In the New Institutional Economics theory, North (1990) suggests that, beyond technological availability, the effectiveness of the financial system is significantly determined by prevailing institutional frameworks. Thus, formal rules, informal norms and enforcement mechanisms shape the behaviours, choices and outcomes of individuals and organisations (North, 1990; Acemoglu, Johnson & Robinson, 2013). The theory suggests that strong institutional quality, characterised by regulatory frameworks, governance and enforcement, creates an enabling environment for ICT adoption and financial inclusion by reducing transaction costs, ensuring fair competition and access to financial services, fostering trust, thereby amplifying the positive effects of ICT on financial inclusion (Davis, Kingsbury & Merry, 2012; Acemoglu et al., 2013). Nonetheless, the theory posits that weak institutions hinder the potential of ICTs to translate into meaningful financial inclusion due to regulatory uncertainty, weak enforcement, and corruption (Davis et al., 2012).

This theoretical perspective posits that while ICT offers potential avenues for expanding financial access, its ultimate impact on financial inclusion is inherently contingent upon the quality of the economy's institutional framework. This underscores the foundational logic for assessing the moderating effect of institutional quality on the relationship between ICT technologies and financial inclusion outcomes in South Africa.

1.2. Empirical Literature

The empirical literature on ICT and financial inclusion has predominantly adopted a regional analytical framework. Concurrently, studies assessing the determinants of financial inclusion have primarily relied on survey-based methodologies. Again, studies on financial inclusion have concentrated on its effects on socio-economic indicators, such as economic growth and poverty, while paying less attention to the factors that affect it. This research addresses a critical gap in the existing literature by conducting a rigorous econometric analysis of the impact of ICT on financial inclusion within the specific context of South Africa. Moreover, it exclusively examines the mediating role of institutional quality in the financial inclusion-ICT nexus, offering a more comprehensive and nuanced perspective.

Regional studies assessing the impact of ICT on financial inclusion, primarily in Africa, Sub-Saharan Africa, Asia, and EU countries, suggest that ICT enhances financial inclusion. For instance, Bayar, Gavriltea and Păun (2021) examined the impact of mobile phone and internet use on financial inclusion in the EU Post-Communist countries between 1996 and 2017, using panel cointegration and causality tests. The study suggests that mobile phone and internet usage have a positive impact on financial institutions and market access. Minh (2022) employed pooled, fixed, and random effects, as well as the Driscoll-Kraay estimation techniques, to assess the impact of ICT on financial development in South Asian countries between 1996 and 2019. The study indicates that ICT is a financial development-promoting factor in Southeast Asian countries. Consistently, the pooled mean group (PMG) analysis by Ong et al. (2023) posits that digitalisation through high-speed broadband and mobile cellular subscriptions bolsters financial inclusion in middle-income Asian economies.

According to Okunade and Alimi (2020), ICT penetration into the financial system has been recognised through the introduction of ICT gadgets such as automated teller machines (ATMs), electronic funds transfer (EFT), electronic purse (E-Purse), and Electronic Wallet (E-Wallet) in Sub-Saharan countries. Richard (2020) used Ordinary Least Squares (OLS) to examine the impact of ICT diffusion on financial inclusion in 52 African countries between 2006 and 2019. The study suggests that the diffusion of ICT increases financial inclusion, penetration, accessibility, and the use of financial services in Africa. Consistently, Hewa Wellalage et al. (2021) indicate that ICT increases entrepreneurs' financial inclusion among 1436 African entrepreneurs. In a similar vein, a generalised method of moments (GMM) analysis by Kouladoun, Wirajing and Nchofoung (2022) reveals that digital technologies enhance financial

inclusion in 43 SSA countries between 2004 and 2019. With similar empirical support, Kanga et al. (2022) and Ahmad et al. (2023) showed that financial technology and ICT tend to improve financial inclusion in 137 and 146 countries, respectively.

While several empirical studies document a positive relationship between ICT and financial inclusion, other recent studies yield mixed findings. For example, a GMM analysis by Adel (2024) revealed heterogeneous effects of technology adoption on financial inclusion across 25 emerging economies in Africa, Asia, and Latin America from 2011 to 2021. The study indicates that technology adoption enhances financial inclusion in Asian economies, exerts an adverse effect in Latin America, and has an insignificant impact on Asian countries. Moreover, the study demonstrated that the influence of institutional quality on financial inclusion varies across different indicators. Specifically, government effectiveness promotes financial inclusion in Africa, while regulatory quality hinders it. In Asia, regulatory quality improves financial inclusion; by contrast, in Latin America, institutional quality indicators show an insignificant relationship with changes in financial inclusion. These inconclusive findings underscore the need to reassess the effect of digital technologies, specifically ICT development, on financial inclusion, particularly at the national level.

Notwithstanding the beneficial effects of digital technology, as affirmed by country-specific analyses of ICT on financial inclusion, the examined literature focuses on direct impacts. For example, Fernandes, Borges, and Caiado (2021) used the autoregressive distributed lag (ARDL) estimation technique to analyse the impact of digital financial services on financial inclusion in Mozambique between 2011 and 2019. The study suggests that digital financial services boost financial inclusion in Mozambique. Pradhan et al. (2021) assessed the dynamics between financial inclusion, ICT development, and economic growth in India. The study indicates that improvement in the development of ICT infrastructure fosters financial inclusion programs. Similarly, Coffie and Hongjiang (2023) suggest that ICT infrastructure in Ghana promotes financial inclusion and provides considerable employment opportunities, contributing to economic growth.

Survey-based research has examined various facets influencing financial inclusion, including challenges, the effect of financial vulnerability, the impact of institutions on a small sample of women, and factors such as unemployment and transaction costs in select rural areas. Subsequently, an evaluation of the current challenges of ICT, financial inclusion, and policy options by Ogbuabor et al. (2020) shows that limited access to financial services is due to poor telecommunications and inadequate infrastructure, high connectivity costs, a lack of education and ICT skills, the digital divide, and low levels of ICT investment. A survey on the financial inclusion effect of financial technology in Egypt by Hussein (2020) indicates that mobile subscribers and internet use have a significant effect on financial inclusion. Aligned with this perspective, Kote, Mendu and Ghodake (2023) indicate that ICT has a considerable effect on financial inclusion services in India.

A qualitative study by Ojo (2022) on the effect of institutional quality and governance on financial inclusion for women in the Gauteng Province of South Africa between 2019 and 2020 suggests that these factors have a minimal impact on financial inclusion for women. Also, Chipunza and Fanta (2022) indicate that financial inclusion is influenced by factors such as education, financial literacy, location, and geographical proximity in South Africa. A qualitative analysis of financial inclusion in rural South Africa by Simatele and Maciko (2022) suggests that most South Africans are financially excluded due to bank charges, limited information, and the distance to the nearest bank branch.

The empirical literature on financial inclusion has documented that the quality of institutions enhances financial inclusion, as institutions govern the rules and operational mechanisms that underpin every aspect of an economy. However, studies assessing the financial effects of institutional quality have focused on its direct impact. Only a few studies considered the direct and its moderating effect on financial inclusion. Also, these studies have yielded mixed results. For instance, the Two-Stage Least Squares (2SLS), Dynamic Ordinary Least Squares (DOLS) and Fully Modified Least Squares (FMOLS) in Yousaf (2021) suggest that legal and political institutions have a positive impact on financial inclusion across 64 countries. Nonetheless, Van et al. (2022) suggest that the effects of institutional quality on financial outcomes are contingent on income level across 19 Asian-Pacific regions between 2004 and 2020. At the same time, the GMM and Ordinary Least Squares (OLS) system analysis by Nsiah and Tweneboah (2023) suggests that institutional quality has a significant impact on financial inclusion in 20 African countries between 2004 and 2020. Additionally, a GMM assessment of the role of institutions on economic growth

and digital finance in Sub-Saharan Africa, by Chinoda and Kapingura (2024), documents a positive influence of institutional quality and governance on the digital financial inclusion-economic growth nexus from 2014 to 2020.

Despite the growing literature on ICT and financial inclusion, country-specific evidence on the moderating role of institutional quality remains limited. Thus, most studies rely on cross-country panels. However, other studies present more contrasting evidence. For example, Doku et al. (2023) used the SGMM technique to examine the moderating effect of institutional quality on the impact of the financial technology-financial inclusion relationship in 34 SSA economies between 2004 and 2021. The study indicates that financial technology enhances financial inclusion, and strong institutions amplify the positive impact of digital finance on it in the region. Yet institutional quality indicators such as government effectiveness, regulatory quality, and control of corruption have a negative and significant effect on financial inclusion in SSA economies. Again, the Quantile regression analysis in Nasreen, Ishtiaq, and Tiwari (2023) ICT and institutions are fundamental to financial inclusion in Asian economies between 2004 and 2020. The study demonstrates a significant yet disparate combined effect of ICT and institutional quality on financial inclusion. Specifically, the beneficial impact of ICT on financial inclusion is diminished in Asian countries characterised by weak legal and regulatory frameworks. In contrast, they are substantially enhanced in those with robust institutional structures.

Nonetheless, a number of studies report a strong positive moderating effect of institutional quality. For instance, Bawuah (2024) examined the effect of institutional quality on the relationship between mobile money and financial inclusion in Ghana between 2014 and 2021. The study suggests that institutional quality and mobile money contribute to financial inclusion, and that institutional quality also significantly moderates the relationship. Even though, Bawuah (2024) considered institutional quality as a moderating factor, the study examined only one component of ICT (mobile money). Again, an analysis of the moderating role of governance on the relationships between social inclusion, ICT and financial inclusion in 46 countries by Bibi et al. (2024) indicate that ICT enhances financial inclusion. The study also reveals that governance with sound ICT infrastructure and socially inclusive communities enhances financial inclusion. In a similar vein, Mbarek (2025) indicates that emerging economies with stronger regulatory frameworks, the rule of law, and political stability experience greater financial inclusion benefits from fintech penetration. Consistently, Yahyaoui (2026) suggests that expanding ICT diffusion and strong institutional frameworks are major driving forces of the development of the financial sector in North African countries.

The empirical literature reviewed demonstrates that, while extensive research has assessed the determinants of financial inclusion across various regions, often focusing on regional analyses that obscure country-specific effects of ICT, a notable void exists for a focused analysis within the South African context. This is noteworthy given South Africa's widespread adoption of ICT, and substantial population segments remain financially excluded. Again, empirical studies on financial inclusion (Cicchello et al., 2021; Chinoda & Kapingura, 2024) have predominantly focused on the macroeconomic implications of financial inclusion, such as its effects on growth, poverty and inequality. However, less attention has been paid to assessing the determinants of financial inclusion.

Furthermore, it is also worth noting that studies (Fernandes et al., 2021; Bawuah, 2024) that assessed the impact of ICT on financial inclusion in other countries, such as Ghana and Mozambique, and focused on commonly used indicators of financial inclusion, including ATM per 100,000, ATM per 1000 km², bank branches per 100,000, and number of credit cards per 1000. The measures capture less information regarding access, depth, and efficiency (Ahmad et al., 2023).

Notwithstanding the valuable contributions of existing survey-based studies, such as those identifying financial inclusion determinants in two South African rural provinces (namely transaction costs, unemployment, and distance) (Simatele & Maciko, 2022), examinations of financial inclusion and vulnerability (Chipunza & Fanta, 2022) or analysis into institutional effects on financial inclusion for a limited sample of women (Ojo, 2022). These analyses predominantly offer qualitative insights. However, they do not provide the robust, quantitative understanding required to determine how ICT econometrically affects financial inclusion at the broader national level. They overlook the nuanced interaction effect of institutional quality. Therefore, the current econometric analysis is comprehensively justified to fill this empirical and analytical gap, econometrically examining the effect of ICT on financial inclusion and the moderating effect of institutional quality on the financial inclusion-ICT nexus. This elucidates significant

implications for South Africa and informs the development of efficient financial inclusion-ICT policies. Thus, to assess the direct and indirect effects of ICT on financial inclusion in South Africa, the study proposes the following hypotheses:

H1: ICT development has a significant positive effect on financial inclusion in South Africa.

H2: Institutional quality has a significant positive effect on financial inclusion in South Africa.

H3: Institutional quality positively moderates the relationship between ICT adoption and financial inclusion in South Africa.

The following section presents the data and methodology used to evaluate the impact of ICT on financial inclusion in South Africa.

2. Research Method

To assess the impact of ICT on financial inclusion in South Africa, the study utilised data from the Global Economy database from 2000 to 2022. This is because data for the main variable, such as institutional quality, are available from 2000 onward. The dependent variable is financial inclusion. The most widely used measure of financial inclusion is the Financial Inclusion Index, developed by Sarma (2015), which is based on three indicators: bank penetration, availability, and usage. Due to data availability challenges in some of the three mentioned indicators, this paper utilises the International Monetary Fund (IMF) Index of Financial Inclusion (Svirydzenka, 2016).

The IMF Financial Inclusion Index is a comprehensive measure based on 20 indicators, combined into six indices that assess the depth, access, and efficiency of financial institutions and markets (Svirydzenka, 2016). Thus, the current study generated the financial index using the Principal Component Analysis (PCA) from six financial inclusion indicators, including the financial institution development depth (*fidd*), financial institution development access (*fida*), financial institutions development efficiency (*fide*), financial markets development depth (*fmdd*), financial market development access (*fmda*) and financial market development efficiency (*fmde*). This IMF index has broader coverage, including two of Sarma's three indicators. Again, it has a longer time coverage to match the current study's dataset. However, this PCA analysis of the six indicators (see Appendix C) revealed that the efficiency indicators (*fide*, *fmde*, and *fmda*) loaded poorly, with loadings below 0.35 and unexplained variance exceeding 15%. The Kaiser-Meyer-Olkin (KMO) test of adequacy was 0.532 (see Appendix D), indicating poor suitability. Therefore, the study dropped the three efficiency indicators and generated the financial inclusion index using *fida*, *fidd* and *fmdd* which capture the access, depth and usage (Beck, Demirguc-Kunt & Martinez Peria, 2007; Sarma, 2008). These three constituents have a Comp 1 explaining 90.36% of the variance (see Appendix C), with all loadings greater than 0.50 and an unexplained variance of less than 0.15, indicating that the constituents measure the same thing. Again, the PCA diagnostics (see Appendix D) show a KMO of 0.740 [>0.70] and Bartlett test of sphericity ($p < 0.000$), indicating sufficient sampling and intervariable correlations for PCA. The current paper employs the IMF financial inclusion indicator following Ahmad et al. (2023), who used it to analyse the relationship between mobile money, ICT, financial inclusion, and growth across 146 countries.

The main regressor is the ICT index, which is also generated using PCA from three ICT constituents: fixed broadband subscription, internet usage, and mobile phone usage (Adeleye & Eboagu, 2019; Olamide et al., 2022). The PCA for ICT indicates that Comp 1 has an eigenvalue of 2.84 and explains 94.6% of the total variance (see Appendix C), confirming the unidimensionality. The KMO value of 0.77 and Bartlett's test p-value of 0.000 (see Appendix D) confirm that the data are suitable for PCA. Again, all three constituents load strongly and positively on Comp 1, with loadings of 0.57-0.58, indicating that they measure the same ICT construct and therefore qualify for inclusion in a single index. Institutional quality is the moderator. It is proxied by the rule of law and political stability. The other four World Governance Indicators (government effectiveness, regulatory quality, control of corruption, and voice and accountability) were excluded due to high collinearity with ICT to avoid multicollinearity in estimation. Gross fixed capital formation is used as the control variable, and the data were obtained from the Global Economy Database. The study also includes the COVID-19 dummy variable to control for structural breaks. The following section presents the model for the present study and the estimation technique used to evaluate the impact of ICT on financial inclusion in South Africa.

2.1. Model Specification

The current research examines the impact of ICT on financial inclusion in South Africa, utilising

time-series data spanning 2000 to 2022. Again, the study considers the moderating effect of institutional quality in the financial inclusion and ICT nexus. This follows Doku et al. (2023), who propose that institutional quality is crucial in the relationship between financial inclusion and digital technology. Therefore, the model of the study takes the form:

$$lfin_t = \beta_0 + \beta_1 lict_t + \beta_2 linst_t + \beta_3 (lict * linst)_t + \beta_4 lgcf_t + \beta_5 covid_t + \varepsilon_t \dots \dots \dots (1)$$

where:

$lfin_t$ is the financial inclusion index, which is the dependent variable. The ICT index is the main explanatory variable. The financial inclusion and ICT indices are generated using PCA (see Akinlo & Okunola, 2021). The PCA normalises all indicators within each dimension to values between 0 and 1, making them independent of the scale on which they were measured (Chinoda & Kwenda, 2019). Again, the PCA minimises the number of variables in a dataset while preserving the most necessary information (Nizam et al., 2020; Greenacre et al., 2023). $inst$ represents the institutional indicators, including the rule of law and political stability. gcf denotes gross fixed capital formation and serves as the control variable. $covid$ represents the COVID-19 pandemic dummy variable. All variables are expressed in logarithmic form (l) to interpret the coefficients as elasticities. β_0 is the constant, and $\beta_1 - \beta_5$ are the coefficients of the predictor variables to be estimated. ε_t is the disturbance term.

The $lict * inst_t$ is the moderated effect variable, which is the product of ICT and institutional quality. This variable measures the effect of ICT on financial inclusion, conditional on institutional quality, as derived below.

$$\frac{\partial lfin}{\partial lict} = \beta_1 + \beta_3 linst \dots \dots \dots (2)$$

where:

β_1 represents the direct effect of ICT innovation, while β_3 captures the moderating effect of institutional quality. All the interaction variables were mean-centred prior to interaction to mitigate structural multicollinearity.

The current paper employs the autoregressive distributed lag (ARDL) approach to assess the impact of ICT on financial inclusion in South Africa. The ARDL estimation technique is a consistent and effective approach for determining cointegration relationships in small samples (Lawal et al., 2016; Nkoro & Kelvin, 2016). It is preferable when dealing with variables that are integrated of different orders 1(1), 1(0), or a combination of both (Nkoro & Kelvin, 2016; Kripfganz & Schneider, 2023). The estimation technique controls for reverse causality and endogeneity bias, making it appropriate for small-sample time series analysis (Fernandes, Borges & Caiado, 2021; Kripfganz & Schneider, 2023). The ARDL model comprises a long-run, a short-run, and an error-correction component (Ahmed et al., 2020). The error-correction model consists of short-term coefficients and an error-correction term. Therefore, the standard ARDL model is specified in Equation 4 as

$$\begin{aligned} \Delta lfin_t = & \beta_0 + \sum_{i=0}^p \beta_{1i} \Delta lfin_{t-i} + \sum_{i=0}^q \beta_{2i} \Delta lict_{t-i} + \sum_{i=0}^q \beta_{3i} \Delta linst_{t-i} \\ & + \sum_{i=0}^q \beta_{4i} \Delta (lict * linst)_{t-i} + \sum_{i=0}^q \beta_{5i} \Delta lgcf_{t-i} + \sum_{i=0}^q \beta_{6i} \Delta covid_{t-i} + \zeta_1 lfin_{t-1} \\ & + \zeta_2 lict_{t-1} + \zeta_3 linst_{t-1} + \zeta_4 (lict * linst)_{t-1} + \zeta_5 glcf_{t-1} + \zeta_6 covid_{t-1} \\ & + \varepsilon_t \dots \dots \dots (3) \end{aligned}$$

where:

β_1 to β_6 represents the short-run dynamics coefficients while ζ_1 to ζ_6 represents the long-run parameters. p and q denote the lag length of the dependent and explanatory variables, respectively. Also i is the lag order. To assess the short-run effects, the study follows the Error Correction Model, which is expressed in Equation 5 in the form:

$$\begin{aligned} \Delta lfin_t = & \alpha_0 + \sum_{i=0}^p \alpha_{1i} \Delta lfin_{t-i} + \sum_{i=0}^q \alpha_{2i} \Delta lict_{t-i} + \sum_{i=0}^q \alpha_{3i} \Delta linst_{t-i} + \sum_{i=0}^q \alpha_{4i} \Delta (lict * \\ & linst)_{t-i} + \sum_{i=0}^q \alpha_{5i} \Delta lgcf_{t-i} + \sum_{i=0}^q \alpha_{6i} \Delta covid_{t-i} + \delta ECT_{t-1} + \\ & \varepsilon_t \dots \dots \dots (4) \end{aligned}$$

where:

δ is the speed of adjustment, ECT_{t-1} is the error correction term. $\alpha_1 - \alpha_6$ are the short-run dynamic

coefficients of the model’s adjustment to the long-run equilibrium. Table 1 presents the definitions and sources of the variables of concern.

Table 1. Definitions of variables

Variable	Definition	Citation	Expected A priori	Data source
fin	Financial Inclusion Index (IMF index)	Ahmad et al. (2023); (Alam et al. (2024)	Dep.var	The author's calculation, using PCA with data from the Global Economy database, for three indicators of financial inclusion: financial institutions development depth, access, and financial markets development depth.
ict	Information and Communication Technology index	Adeleye and Eboagu (2019); Olamide et al. (2022)	+	GED Author’s calculation: Generated from three ICT constituents, including internet usage, fixed broadband subscription and mobile phone usage
inst	Institutional quality captures the effectiveness, efficiency, and reliability of society's governing systems, regulatory frameworks, and laws. It is proxied by two individual indicators: the rule of law (rlw), which captures the enforcement of contracts and property rights, and political stability (pls), which captures the absence of policy uncertainty.	Ongo Nkoa and Song (2022); Chinoda and Kapingura (2024)	+	GED
icinst	The interaction between ICT and each institutional quality indicator (rule of law, political stability)	Doku et al., 2023 and Bawuah (2024),	+	Author’s computation using ICT and institutional quality indicators,, including rule of law and political stability data from GED
gcf	Gross fixed capital formation (% of GDP) is a macroeconomic measure of a country’s investment in long-term physical assets, such as machinery, buildings, and infrastructure.	(Haque, Abdul & Akhtar, 2026)	+	GED
covid	Captures the effect of the COVID-19 pandemic period on financial inclusion. It is measured by 1 for years 2020-2022 and 0 for years 2000-2019	(Avom & Kamdem, 2025; Chipeta et al., 2026)	+/-	The author's computation.

Source: *Author*

Based on the literature in Table 1, ICT, institutional quality, and gross capital formation are expected to have a positive impact on financial inclusion, while the COVID dummy variable is expected to have a positive or negative effect. The next section presents the empirical results of the current study.

3. Results and Discussions

Before empirical assessment, the study presents summary statistics and examines the correlation coefficient and unit root tests. The study employs stationarity tests to establish whether the series is integrated of order 0 or 1, rather than order 2, which is a prerequisite for the ARDL Bounds test method. The study employs the Augmented Dickey-Fuller (ADF)test as well as the Phillips-Perron (PP) test (see Table 2), which work well in the case of a small sample (Ajewole, Adejuwon & Jemilohun, 2020).

Table 2. Descriptive statistics

Variable	Obs	Mean	Std. dev.	Min	Max
fin	23	8.02e-09	1.646	-2.763	2.247
fida	23	.304	.0982	.17	.425
fidd	23	.566	.068	.445	.647
fmdd	23	.635	1.000	.449	.786
ict	23	-7.77e-09	1.685	-2.390	2.437
fbs	23	1.480	1.105	.010	3.250
itu	23	33.906	26.245	5.350	73.100
mcs	23	108.005	52.579	17.810	168.920
rlw	23	.026	.121	-.240	.180
pls	23	-.184	.218	-.750	.220
gcf	23	16.950	2.140	12.540	21.290
covid	23	.1304	.344	0	1

Source: *Author*

Table 2 presents descriptive statistics for the variables under consideration between 2000 and 2022. Due to the abstract nature of the composite indices generated by PCA, the descriptive statistics for the financial inclusion and ICT indices lack a direct economic interpretation. For example, PCA indices are centred at zero and lack a natural scale. Therefore, to provide meaningful insights into the data structure and characteristics of the sample, the paper reports summary statistics for the constituents of each index. Therefore, the descriptive statistics table indicates that financial inclusion indicators improved over time, with financial institution development access (*fida*) averaging 0.3 and increasing from 0.17 to 0.43. Financial institution development depth (*fidd*) and financial markets development depth (*fmdd*) recorded higher means of 0.57 and 0.64, rising from 0.45 to 0.65 and 0.45 to 0.79, respectively. Suggesting usage and depth grew faster than access. Table 1 shows that ICT development between 200 and 2022 was mobile-led, with mobile cellular use averaging 108 and expanding from 17.8 to 168.9 per 100 people, while internet usage grew from 5.5% to 73%. The fixed broadband subscription remained low at 1.5 on average. Institutional quality was weak, with rule of law and political stability averaging 0.03 and -0.18, respectively. The gross fixed capital formation averaged 16.95% of GDP, ranging from 12.54% to 21.29%, consistent with typical levels for developing economies such as South Africa. The COVID-19 dummy has a mean of 13%, indicating that 3 of the 22 years correspond to the COVID pandemic. The descriptive statistics show that ICT, particularly mobile phone use, improved substantially, while financial inclusion improved modestly, and institutions remain weak, with fluctuations. This motivates testing whether ICT growth drives financial inclusion and whether institutions moderate the financial inclusion-ICT nexus in South Africa. The following table (Table 3) presents unit root tests for the study's variables.

Table 3. Unit root test results

Variable	Augmented Dickey Fuller (ADF) test		Phillips Perroni (PP) test	
	I(0)	I(1)	I(0)	I(1)
lfin	-0.629	-4.659***	-0.535	-5.010***
liict	-2.394	-2.921**	1.922	-2.928**
lrlw	-2.625	-5.835***	-2.616	-5.823***
lpls	-1.337	-5.497***	-0.967	-7.650***
lgcf	-1.569	-3.804***	-1.569	-3.750***
covid	-0.309	-4.583***	-0.309	-4.583***

*** p<0.01, ** p<0.05, * p<0.1 : asterisks denote 1,5,10 per cent significant levels.

Source: *Author*

The results of the ADF and PP tests show that all variables are stationary in first differences and that none is integrated of order 2. Thus, an ARDL Bound test is applicable to the model of the study.

Table 4. Bound tests

F-Bounds Test_rlw			F-Bounds Test_pls		
Test Stat.	Value	K	Test Stat.	Value	k
F-statistic			F-statistic		
Long-run	7.03	5	Long-run	9.45	5
Significance	Lower Bound	Upper Bound	Significance	Lower Bound	Upper Bound

F-Bounds Test_rlw			F-Bounds Test_pls		
10%	2.26	3.35	10%	2.26	3.35
5%	2.62	3.79	5%	2.62	3.79
2.5%	2.96	4.18	2.5%	2.96	4.18
1%	3.41	4.68	1%	3.41	4.68

Source: *Author*

The Bound test results in Table 4 indicate that there is long-run co-integration among the variables of concern, as the value of the F-statistic (7.03;9.5) exceeds both the lower and upper bounds. Consequently, the null hypothesis of no co-integration is rejected for the modelled series. Therefore, long and short-run ARDL estimation is a preferable estimation technique for the analysis. Table 5 delineates empirical results of the short-term impact of ICT on financial inclusion.

Table 5. Short-run coefficients

Dep Var: Financial inclusion(<i>lfin</i>)		
Variable	ARDL (1,1,0,1,1,0) Model_1_rlw	ARDL (1,0,1,1,0,0) Model_2_pls
d(lict)	0.115 (0.196)	0.446*** (0.118)
d(lrlw)	-0.054 (0.618)	
d(lpls)		-0.124 (0.265)
d(lgcf)	-1.145* (0.574)	-2.228*** (0.423)
d(covid)	-0.240 (0.229)	-0.388 (0.268)
C	-12.040*** (2.482)	-10.687*** (1.221)
ECT(-1)	-0.628*** (0.081)	-0.617*** (0.070)
Interaction terms		
d(lict_lrlw)	-0.907* (0.524)	
d(lict_lpls)		-0.929*** (0.298)

*** p<0.1, ** p<0.05, *** p<0.01

Source: *Author*

The short-run results show that ICT has a direct positive and statistically significant effect on financial inclusion. Thus, a 1% increase in ICT development increases financial inclusion by 0.5% at the 1% level. The results align with the Technology Acceptance Model, which suggests that ICT is beneficial for the use and adoption of financial products and services.

Table 5 reveals that a 1% increase in gross fixed capital formation reduces financial inclusion by 1.2% to 2.2% at 10% and 5% levels. This indicates that short-term increases in capital investments lead to short-term contraction in financial inclusion, respectively. This confirms a resource crowding-out effect in which heavy initial spending and long-term capital investments, including transport networks, electrical grids, and cellular tower construction, crowd out financial inclusion initiatives. This result aligns with Castilho and Fuinhas (2024) and Abokyi and Bettin (2025), who suggest that short-term investments may prioritise sectors with immediate returns, neglecting inclusive policies, thereby reducing financial inclusion.

Furthermore, the interaction terms of ICT and institutional quality indicators are negative and significant. This implies that institutions come with a regulatory burden that dampens the positive effect of ICT on financial inclusion. Table 6 presents the long-run effect of ICT on financial inclusion in South

Africa.

Table 6. Long-run coefficients

Variable	Model_pls	Model_pls
lict	0.724*** (0.084)	0.723*** (0.058)
lrlw	-0.086 (0.978)	
lpls		-1.361*** (0.469)
lgcf	5.470*** (1.225)	4.955*** (1.005)
covid	-0.240 (0.319)	-0.630*** (0.216)
Interaction terms		
lict_lrlw	-1.443* (0.820)	
lict_lpls		-1.506*** (0.304)
C	-12.040*** (2.482)	
Sample (adjusted)	2001-2022	2001-2022
Include observations	22 after adjustments	22 after adjustment
Max dependent lags	1	1
Dynamic regressor lag	1 lag	1 lag
Model selection method	Schwarz info criterion (SIC)	Schwarz info criterion (SIC)

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$ Source: *Author*

Table 6 indicates that ICT development has a positive and significant impact on financial inclusion in the long run. Thus, a 1% increase in ICT results in a 0.7% increase in financial inclusion at a 1% significance level. The positive effect in both short- and long-run horizons confirms ICT's role as a fundamental enabler of sustainable financial inclusion once systemic adoption occurs. The result aligns with the Technology Acceptance Model and Diffusion of Innovation theories, which advocate that ICT increases the use and adoption of financial products and services. Also, the result aligns with Bayar, Gavriletea and Păun (2021), Doku et al. (2023) and Bawuah (2024), who suggest that ICT indicators, including internet use, mobile phone use, and fixed broadband subscriptions, operate through lower transaction costs and wider network coverage, thereby expanding access for the previously unbanked and enhancing financial inclusion.

The results show a negative and statistically significant effect of institutional quality on financial inclusion in the long run. This result is inconsistent with the study's a priori expectations. Thus, a 1% increase in institutional quality, proxied by political stability, is associated with a 1.4% decrease in financial inclusion ($p < 0.01$). This implies that as institutional quality strengthens, the financial sector implements stricter regulatory controls and risk assessment mechanisms, making it harder for low-income populations and informal entrepreneurs to access formal financial services due to strict documentation requirements. This finding aligns with Doku et al. (2023), who documented the negative effects of institutional quality indicators, such as political stability, rule of law, and regulatory quality, on financial inclusion in SSA economies.

Regarding the interaction terms, the findings reveal that the interactions between ICT development and the rule of law and between ICT development and political stability are negative and statistically significant. This implies that institutional rigidities are diminishing the developmental gains of technology development. Indeed, the results suggest that as legal frameworks and stability improve, the regulatory frameworks governing financial platforms become more restrictive. This eventually reduces ICT capacity, lowers entry barriers, and incorporates underserved demographics into the formal financial sector, leading

to low financial inclusion. The direct, and moderating negative effect of institutional quality aligns with the regulatory burden perspective, which suggests that a strict institutional framework can increase compliance costs and entry barriers for ICT-based financial providers (Djankov et al., 2002). Consistently, the results align with Demircuc-Kunt et al. (2018), who found that rigid licensing requirements can exclude low-income users from formal digital financial services. This result is consistent with Nasreen, Ishtiaq, and Tiwari (2023) who suggest that the institutional quality diminishes the beneficial impact of ICT on financial inclusion in Asian countries

The results reveal that gross fixed capital formation promotes financial inclusion in the long run. Hence, a 1% increase in capital investment increases financial inclusion by 5% ($p < 0.01$). This implies that long-term investments in physical infrastructure eventually create the necessary foundation for financial institutions and digital networks to expand financial service delivery to underserved and marginalised population segments. This result corroborates the work of Haque and Akhtar (2026), which shows that increased investment in fixed assets, including financial infrastructure, lays the foundation for financial institutions to scale operations and integrate the underserved and excluded segments into the formal financial system, thereby boosting the BRICS economies.

The negative, statistically significant COVID dummy indicates that financial inclusion during the COVID-19 period was 0.63 units lower compared to the pre-pandemic period. This implies that the pandemic led to a downward shift in the baseline for financial inclusion between 2020 and 2022. This result is consistent with Chipeta et al. (2026), who suggests that COVID-19 pandemic-induced financial hardships significantly deterred the adoption of digital financial services in Africa.

3.1. Diagnostic Tests

The study performed diagnostic tests to validate the results of the time-series ARDL estimation technique. Thus, the F-stat probability should be less than 0.05%. Durbin Watson-stat should be ≥ 2 . The Jarque-Bera (J-Bera) p-value should be greater than 0.05%. The B-Godfrey serial correlation of the LM Breusch-Pagan-Godfrey Heteroscedasticity test p-values should be greater than 0.05%. Again, the Cumulative Sum (CUSUM) and Cumulative Sum of Squares (CUSUMQ) lines should lie between the 95% significance lines to ascertain model stability. The diagnostic test results for the ARDL estimation are shown in Table 7.

Table 7. Diagnostic test results

Test Specification	Test statistics_rlw	Test statistics_pls	Decision
Adjusted R-Squared	0.76	0.82	Very good fit of the model to the data
F-Statistic	17.353 (0.000)	31.748 (0.000)	Models are a good fit
Durbin-Watson Statistic	2.8	2.5	No autocorrelation
Jarque-Bera Normality Test	1.115 (0.573)	0.777 (0.678)	Residuals in all models are normally distributed
LM Serial Correlation Test	1.181 (0.338)	1.642 (0.242)	no serial correlation
Breusch-Pagan Heteroscedasticity Test	12.860 (0.169)	6.976 (0.543)	No heteroscedasticity
Ramsey RESET Test	0.398 (0.368)	1.082 (0.300)	Models are correctly specified

Note: Probability values are in parentheses

Source: *Author*

The diagnostic test results in Table 7 confirm the models' goodness of fit, with residuals demonstrating normality, no evidence of serial correlation, heteroscedasticity, and adherence to the assumption of correct specification. Again, the CUSUM and CUSUMQ lines (see Appendix F) lie between the 5% critical boundaries, indicating that the models are stable. The following table (Table 8) presents the FMOLS estimates for the robustness check of the long-run relationship.

Table 8. Robust check: FMOLS

Variable	Model_pls	Model_pls
lict	0.834*** (0.079)	0.957*** (0.093)
lrlw	-0.821 (0.982)	
lpls		-1.724** (0.793)
lgcf	3.431*** (0.996)	0.253 (1.384)
Covid	-0.202 (0.366)	-0.494 (0.593)
Interaction terms		
lict_lrlw	-1.205* (0.6404)	
lict_lpls		-0.842 (0.588)

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Source: *Author*

The FMOLS results are qualitatively consistent with the ARDL estimates, particularly for the key variables. The slightly weaker significance of some variables under FMOLS is consistent with its reduced efficiency in small samples. Thus, the study relies on the ARDL results as baseline estimates, with FMOLS used only for robustness checks.

4. Conclusions

South Africa has seen a growth in the usage of digital financial technology, specifically through ICT development. In light of this, the current paper examined whether the increased use of ICT contributed to higher financial inclusion in the country between 2000 and 2022. Recognising the importance of a favourable environment for the effective development and promotion of digital finance technology, the study also assessed the possible moderating influence of institutional quality in the link between ICT and financial inclusion. The paper presents policy implications and recommendations based on the results of the study.

Empirical findings demonstrate that ICT development has a positive and significant impact on financial inclusion in both short and long-term horizons. Again, the results demonstrate that institutions negatively affect financial inclusion in the long run. Regarding the interaction term, the results indicate that institutional quality reduces the positive effect of ICT development on financial inclusion in South Africa in the long run.

The results also reveal that gross fixed capital formation initially lowers financial inclusion but ultimately increases it in the long term. At the same time, the COVID pandemic lessened the baseline level of financial inclusion between 2020 and 2022 compared to 2000 and 2019.

Policy Implications

The positive short and long-term effects suggest that, over time, ICT acts as a powerful enabler for financial inclusion. This underscores ICT as a critical long-term strategic asset for achieving sustainable financial inclusion.

The direct negative effects of institutional quality challenge the notion that institutions are inherently beneficial. At the same time, the negative effect of the interaction between ICT and institutional quality highlights a crucial misalignment between national regulatory frameworks and financial inclusion. This confirms that digital infrastructure alone cannot drive financial inclusion unless it is supported by flexible pro-poor regulatory frameworks. Meaning that if institutions remain rigid, digital infrastructure actually fails to yield financial inclusion.

The capital-investment asymmetry pattern implies that the initial phases of infrastructure carry hidden short-term costs for the financial ecosystem. That is when resources are heavily committed to investing in digital financial infrastructure, and local markets may face an immediate crowding-out effect that restricts financial access for small businesses and low-income segments. Nonetheless, the long-run positive effect implies that long-term investment in physical infrastructure is a crucial prerequisite for financial depth.

The negative effect of the COVID dummy variable shows that the pandemic, associated with digital acceleration, reduced financial inclusion. This implies that, even though ICT tools were expanding during this period, increasing economic hardships, job losses, and income declines limited people's ability to participate in the formal financial system over the three-year period.

Policy Recommendations

In light of the observed positive effect of ICT on financial inclusion, the government and policymakers should prioritise ongoing, significant investment in upgrading affordable, high-speed broadband and mobile network coverage, particularly in underserved and marginalised areas, as this forms the enduring backbone of digital financial inclusion. The South African financial institutions should cultivate a regulatory and market framework that promotes the sustained development of inclusive, user-centric digital financial products and services, thereby leveraging emerging ICT technologies to enhance long-term financial participation.

To lessen the negative impact of institutional quality on financial inclusion, policymakers should prioritise systemic institutional reforms. This includes conducting thorough reviews to identify and eliminate exclusionary regulations and bureaucratic hurdles that restrict financial access, while enhancing transparency and strictly combating corruption within financial institutions and regulatory frameworks. Moreover, the government and policymakers should balance institutional enforcement with regulatory flexibility to avoid excluding vulnerable population segments.

In response to the observed negative interaction term (*ICT*institutions*) between institutional quality and financial inclusion, policy efforts should prioritise implementing institutional reforms that address the direct exclusionary practices within the financial sector. These include streamlining processes and enhancing transparency. Again, maximising the benefits of technology development requires changing how laws are enforced. Thus, policymakers should not just enforce them more strictly. Therefore, to protect consumers without erasing the benefits of ICT, financial policymakers and the central bank should adopt regulatory sandboxes and tiered know-your-customer mechanisms, with low-value mobile accounts requiring less documentation than high-value commercial accounts.

This paper assessed the financial inclusion effect of ICT in South Africa only. Moreover, the study employed an aggregated analysis. Further study should enhance the established findings by examining the impact of ICT on financial inclusion at the provincial level in South Africa and by exploring other policy instruments that can enhance financial inclusion in South Africa and other countries where ICT is evolving.

Conflict of Interest

No conflict of interest.

Ethical Considerations

This article adhered to all ethical standards for research, involving no direct contact with human or animal subjects.

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Data Availability

Publicly available datasets were analyzed in this study. This data can be found here [<https://www.theglobaleconomy.com/>; <https://databank.worldbank.org/source/world-development-indicators> ; <https://www.rug.nl/ggdc/productivity/pwt/?lang=en>]. The raw data will be made available by the corresponding author on request.

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APPENDIX

Appendix A. Correlation coefficients

	lfin	lict	lrlw	lpls	lgcf
lfin	1.000				
lict	0.911*	1.000			
lrlw	-0.385*	-0.365*	1.000		
lpls	-0.154*	-0.408*	0.220*	1.000	
lgcf	0.070	-0.136	0.343*	0.733*	1.000

*** p<0.01, ** p<0.05, * p<0.1

Appendix B: Variance Inflation Factor (VIF) Results

Variable	VIF	1/VIF
Lpls	2.90	0.345
Lgcf	2.72	0.367
Lict	1.55	0.646
Lrlw	1.37	0.732
Mean VIF	2.13	

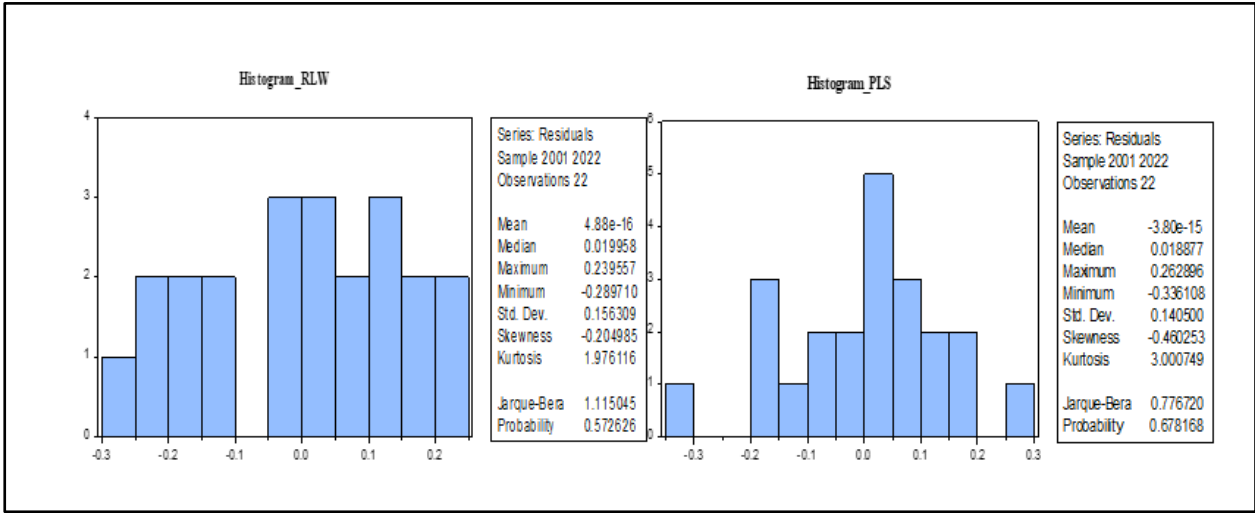
Appendix C: Principal Components and Eigenvectors

Financial inclusion _6-components							
Variable	Component	Eigenvalue	Difference	Proportion	Cumulative	Comp 1	Unexplained
nfida	Comp1	3.088	1.968	0.515	0.515	0.506	.211
nfidd	Comp2	1.120	.185	0.187	0.701	0.525	.148
nfide	Comp3	.936	.255	0.156	0.857	0.222	.848
nfmda	Comp4	.681	.536	0.113	0.971	0.027	.998
nfmddd	Comp5	.144	.113	0.024	0.995	0.556	.046
nfmdede	Comp6	.0316	.	0.005	1.000	0.331	.661
Financial inclusion_ 3-components							
Variable	Component	Eigenvalue	Difference	Proportion	Cumulative	Comp1	Unexplained
nfida	Comp1	2.711	2.505	0.904	0.904	0.565	.136
nfidd	Comp2	.206	.1218	0.069	0.972	0.579	.092
nfmddd	Comp3	.084	.	0.028	1.000	0.588	.061
ICT_3-components							
Variable	Component	Eigenvalue	Difference	Proportion	Cumulative	Comp1	Unexplained
nfbs	Comp1	2.838	2.732	0.946	0.946	0.575	.061
nitu	Comp2	.106	.050	0.035	0.981	0.575	.063
nmcs	Comp3	.056	.	0.019	1.000	0.583	.037

Appendix D: Diagnostics for Principal Component Analysis

Index	Bartlett test	KMO test
fin-6-components	0.000	0.532
fin- 3-components	0.000	0.740
inst-6-components	0.000	0.643
ict_3-components	0.000	0.766

Appendix E. Histogram



Appendix F: CUSUM and CUSUMQ plots

